

ECBC-TR-

**DOMESTIC PREPAREDNESS PROGRAM:
TESTING OF RAE SYSTEMS ppbRAE
VOLATILE ORGANIC COMPOUND (VOC) MONITOR
PHOTO-IONIZATION DETECTOR (PID)
AGAINST CHEMICAL WARFARE AGENTS
SUMMARY REPORT**

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September 2001

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Soldier and Biological Chemical Command, AMSSB-RRT, Aberdeen Proving Ground, MD 21010-5424

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13. ABSTRACT (Maximum 200 words) This report characterizes the chemical warfare (CW) agent detection potential of the commercially available ppbRAE Photo-ionization Detector (PID). The instrument was tested against HD, GB, and GA vapor under various conditions. This report is intended to provide the emergency responders concerned with CW agent detection an overview of the detection capabilities of the ppbRAE PID.				
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PREFACE

The work described herein was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Soldier and Biological Chemical Command (SBCCOM) Program Director for Domestic Preparedness. This work was started in February 2000 and completed in May 2000.

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TABLE OF CONTENTS

1.	INTRODUCTION.....	7
2.	OBJECTIVE.....	8
3.	SCOPE	8
4.	DETECTOR DESCRIPTION	8
5.	TEST PROCEDURES	10
5.1	CALIBRATION	10
5.2	AGENT VAPOR CHALLENGE.....	10
5.3	AGENT VAPOR QUANTIFICATION.....	11
6.	RESULTS AND DISCUSSION	12
6.1	CALIBRATION	12
6.2	MINIMUM DETECTABLE LEVELS.....	12
6.3	RESPONSE FACTORS.....	13
6.4	TEMPERATURE AND HUMIDITY EFFECTS	14
7.	CONCLUSIONS	16
	LITERATURE CITED	17

TABLES

1.	Minimum Detectable Level (MDL) for ppbRAE at Ambient Temperatures and 5% Relative Humidity.....	13
2.	Range of Response Factors for the ppbRAE against HD, GA, and GB at Various Conditions with Corresponding MiniRAE Plus Results	14
3.	Range of Response Factors of ppbRAE units at Several Agent Concentrations and Various Temperature and Relative Humidity Conditions	15

FIGURE

1.	ppbRAE Volatile Organic Compound Detector.....	9
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1. INTRODUCTION

The Department of Defense (DOD) formed the Domestic Preparedness (DP) Program in 1996 in response to Public Law 104-201. One of the objectives is to enhance federal, state, and local capabilities to respond to Nuclear, Biological and Chemical (NBC) terrorism incidents. Emergency responders who encounter either a contaminated or a potentially contaminated area must survey the area for the presence of either toxic or explosive vapors. Presently, the vapor detectors commonly used are not designed to detect and identify chemical warfare (CW) agents. Little data are available concerning the ability of these commonly used, commercially available detection devices to detect CW agents. Under the DP Expert Assistance (Test Equipment) Program, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to address this need. The Applied Chemistry Team (ACT), formerly known as the Design Evaluation Laboratory (DEL), Aberdeen Proving Ground, Edgewood, Maryland, performed the detector testing. ACT is tasked with providing the necessary information to aid authorities in the selection of detection equipment applicable to their needs.

Reports of the instrument evaluations are posted in the Homeland Defense website (<http://www2.sbccom.army.mil/hld/downloads/index.htm>) for public access. Instruments evaluated and reported in 1998 and in 1999 include:

MiniRAE plus from RAE Systems, Inc.

Passport II Organic Vapor Monitor from Mine Safety Appliance Corp.

PI-101 Trace Gas Analyzer from HNU Systems, Inc.

TVA 1000B Toxic Vapor Analyzer from Foxboro Company

Draeger Colorimetric tubes (Thioether and Phosphoric Acid Ester) from Draeger Corp.

MicroFID detector from Photovac, Perkin Elmers Corp.

MIRAN Sapphire Air Analyzer from Foxboro Corp.

Mine Safety Colorimetric (HD and Phosphoric Acid) Tubes from Mine Safety Corp.

M90D1-C Chemical Warfare Detector from Environics OY, Finland

APD2000 Air Monitor from Envirotech Inc.

In 2000, the evaluation of instruments continued to include the ppbRAE Photo-Ionization Detector from RAE Systems (Sunnyvale, CA), the SAW MiniCAD mkII from MicroSensor Systems (Bowling Green, KY), UC AP2C Monitor from Proengin (France), the SABRE2000

from Barringer Instruments Inc. (Warren, NJ), and the CAM (Type L) from Graseby Dynamics Ltd (Herts, UK). Each of these evaluations will be reported separately. This report pertains to the evaluation of the ppbRAE Photo-Ionization Detector from RAE Systems.

2. OBJECTIVE

The objective of this report is to assess the capability and general characteristics of the ppbRAE Photo-Ionization Detector to detect chemical warfare agent vapors. The intent is to provide the emergency responders, concerned with CW agent detection, an overview of the detection capabilities of this instrument.

3. SCOPE

The evaluation attempts to characterize the CW agent vapor detection capability of the ppbRAE detector. Due to time and resource limitations, the investigation is only concerned with testing against Tabun (GA), Sarin (GB), and Mustard (HD) under various conditions. These representative CW agents are believed to be the most likely threats. Test procedures followed the established Domestic Preparedness Detector Test and Evaluation Protocol developed in the Phase 1 Test Report¹. The test concept was as follows:

- a. Determine the Minimum Detectable Level (MDL), which is the lowest concentration level where repeatable detection readings are achieved for each CW agent tested. The current military Joint Services Operational Requirements (JSOR)² for point sampling detectors served as a guide for detection sensitivity objectives.
- b. Investigate the humidity and temperature effects on detection response.
- c. Determine the Response Factors (RF) for each CW agent at several concentrations and conditions.
- d. Observe the effects of potential interfering vapors upon detection performance in the laboratory and in the field.

4. DETECTOR DESCRIPTION

RAE Systems Inc., Sunnyvale, California (<http://www.raesystems.com/home1.html>) is the manufacturer of the ppbRAE parts per billion (ppb) Volatile Organic Compound (VOC) Monitor (Model PGM-7240). According to the manufacturer, the ppbRAE is a Photo-Ionization Detector (PID) with standard 10.6 eV or optional 9.8 or 11.7 eV UV lamp. The ppbRAE is a durable, lightweight (19.5 oz., including the battery pack), handheld detector designed for continuous monitoring of dangerous environments for VOCs at ppb levels. Alarm levels can be preset for low, high, short-term exposure limit (STEL), and the time weighed average (TWA) levels. There is an audible alarm as well as a visual flashing red LED, along with the direct ppb display readout. The detector also has point data logging capability for post event downloading to a personal computer.

The ppbRAE uses a dual channel PID and an electrodeless discharge ultra-violet (UV) lamp as the high-energy photon source. The built-in sample pump draws in the vapor sample at a nominal flow rate of 400 cc/minute. The sample passes by the UV lamp where it is photo-ionized enabling the electrons to be detected as current by the photo-multiplier sensor. The

instrument uses the sensor readings to calculate the gas concentrations based on a known response factor derived from a referenced calibration gas. The ppbRAE was evaluated in its “Hygiene” mode where the monitor runs continuously and the LCD displays instantaneous readings. The operable temperature is given as 14°F to 113°F (-10°C to +40°C), and the relative humidity (RH) range from zero to 95%.

Figure 1 is a digital photograph of the ppbRAE detector. Three units were loaned by the manufacturer for this evaluation and randomly labeled A, B, and C. At the beginning of the evaluation, units A and B were equipped with the 10.6eV UV lamps and the C unit used the 11.7 eV UV lamp. The intent was to evaluate the relative performance of the 10.6 and 11.7eV lamps. However, the 11.7eV lamp was found to perform erratically and was unsuitable for the evaluation. A RAE Systems representative concurred that the 10.6eV lamps would have the longest life and provide sufficient energy for best resolution for CW agents detection. Therefore, all three units were fitted with the 10.6 eV lamps, and two units were tested. Units A and B were tested and the C unit was designated as a backup. However, unit C was entered into the evaluation after problems were encountered with unit B. In general, two units were tested throughout the evaluation depending on which two were usable on any given day.



Figure 1. ppbRAE Volatile Organic Compound Detector

The instrument can operate on four AA batteries or the rechargeable Nickel Metal Hydride battery pack. The unit has a built-in battery-charging feature that can operate the instrument and recharge the battery pack using 110V AC. During this evaluation, the units were

connected to AC power to ensure that the detector performance would not be affected by battery condition.

5. TEST PROCEDURES

5.1 CALIBRATION

Calibration instructions were followed according to the ppbRAE Operation and Maintenance Manual,³ where applicable. Calibration allows the detector to display the detected sample concentration in parts per billion (ppb) units equivalent to a 10,000 ppb isobutylene calibration (span) gas. The startup procedure takes approximately five minutes and the instrument was allowed to stabilize before the calibration. The calibration procedure requires setting the detector baseline zero point by challenging the unit with either zero air or the conditioned air of the agent generation system. Then the detector is challenged with the calibration gas to set the sensitivity span of the instrument. This means setting the instrument to read 10,000 ppb when challenged with the 10,000 ppb isobutylene. Once this is set, the instrument is ready for use.

Readings obtained from the instrument when challenged with CW agent vapor concentrations are used to calculate the corresponding response factors (RF). The RF values for any given detector model should be consistent across concentrations, temperatures, RH, and between different units so that the RF can be programmed into the detector's memory as suggested in the instruction manual. RF values can then be correlated to the equivalent CW agent concentration assuming that the sample contains a certain CW agent.

According to the manufacturer, calibrations are supposed to hold true for several weeks and no daily instrument calibration is "required" because calibrations and settings are programmed into the detector. However, for the purpose of this evaluation, confirmation of the sensitivity of the instruments was performed with the span gas each day before testing. The unit was usually found in need of re-calibration because the reading was not within 10% of the expected 10,000 ppb value.

5.2 AGENT VAPOR CHALLENGE

The agent challenges were conducted using the Multi-Purpose Chemical Agent Vapor Generation System⁴ with Chemical Agent Standard Analytical Reference Material (CASARM) or the highest purity CW agents available. The vapor generator system permits testing of the instrument with humidity and temperature-conditioned air without agent vapor to assure background air does not interfere before challenging it with similarly conditioned air containing the CW agent vapor. The ppbRAE detector was conditioned at the desired temperature and humidity using the vapor generator system air for approximately one minute to establish the stable "background reading" of the detector prior to the agent challenge. This background reading (baseline) at the testing condition is required to establish the net detector response from the agent challenge reading. The net detector reading is the challenge reading minus the background reading.

Agent challenge begins when the solenoids of the vapor generation system are energized to switch the air streams from conditioned air only to similarly conditioned air containing the agent. Each detector was tested three times under each condition. Detector response readings

were recorded every 30 seconds during the 3-5 minute agent challenge.

The ppbRAE units were tested with the agents GA, GB, and HD at different concentration levels at ambient temperature and low relative humidity (<5% RH) in an attempt to determine the MDL. This was done because the calibration span gas uses “zero” air as a dilutant. The detectors were also tested at relative humidity conditions of approximately 50% and 90% at ambient temperatures, as well as the temperature extremes of -10°C (GA and GB), 0°C for HD, and +40°C (GA, GB and HD) to observe temperature and humidity effects. Temperature extremes were based on the manufacturer’s stated operating range using agent concentrations that approximated the MDL. Although HD freezes at approximately +15°C, the calculated HD volatility of 92 mg/m³ at 0°C easily produces a vapor concentration higher than the 2 mg/m³ JSOR detection criteria allowing the instrument to be evaluated at 0°C.

The detection response from the CW agent challenge in ppb was observed and recorded. The response readings are equivalent ppb responses from the isobutylene calibration gas. The response factor (RF) for the particular CW agent tested is derived and serves as an indication of the relative sensitivity of a detector to the concentration of a compound vapor compared to the calibration gas used. Calculated RF values for different compounds are commonly entered into a detector’s memory to enable the instrument to automatically display the correct concentration readings of those compounds. The RF is calculated by dividing the actual concentration in the test air (in ppb) by the net detector reading (in ppb).

$$\text{Response Factor} = \frac{(\text{Actual Challenge Concentration})}{(\text{Detector Reading}) - (\text{Background Reading})}$$

Hence, isobutylene will have a response factor of:

$$\frac{(10,000 \text{ PPB})}{(10,000 \text{ PPB}) - (0 \text{ PPB})} = 1.0$$

Ideally, RF values for a compound should be constant at varying concentrations. A higher RF value indicates the detector is less sensitive in detecting that compound vapor.

5.3 AGENT VAPOR QUANTIFICATION

The generated agent vapor concentrations were analyzed independently and reported in both milligrams per cubic meter (mg/m³) and in parts-per-million (ppm) units in the results tables. The vapor concentration was quantified by utilizing the manual sample collection methodology⁵ using the Miniature Continuous Air Monitoring System (MINICAMS[®]) manufactured by O. I. Analytical, Inc., Birmingham, Alabama. The MINICAMS[®] is equipped with a flame photometric detector (FPD), and it was operated in either phosphorus mode for the G agents or sulfur mode for HD.

This system normally monitors air by collection through sample lines and subsequently adsorbing the CW agent onto the solid sorbent contained in a glass tube referred to as the pre-concentrator tube (PCT). The PCT is located after the MINICAMS[®] inlet. Then the concentrated sample is periodically heat desorbed into a gas chromatographic capillary column for subsequent separation, identification, and quantification. For manual sample collection, the PCT was removed from the MINICAMS[®] during the sampling cycle and connected to a

measured suction source to draw the vapor sample from the agent generator. The PCT was then re-inserted into the MINICAMS[®] for analysis. This “manual sample collection” methodology eliminates potential loss of sample along the sampling lines and the inlet assembly when the MINICAMS[®] is used as an analytical instrument. The calibration of the MINICAMS[®] was performed daily using the appropriate standards for the agent of interest. The measured mass equivalent (derived from the MINICAMS chromatogram) divided by the total volume (flow rate x time) of the vapor sample drawn through the PCT produces the sample concentration that converts into mg/m³.

6. RESULTS AND DISCUSSION

6.1 CALIBRATION

The instruments were calibrated with the 10,000 ppb isobutylene calibration gas before each day of testing and rechecked after the agent challenges to observe residual effects and/or calibration drift. The detectors were found to require frequent calibration during the evaluation. Whenever the result varied by >10%, the instrument was re-calibrated. This happened several times a day. Calibration gas checks before and after agent exposures showed definitive calibration drifts which eventually lead to re-calibrating the units after each use.

The frequent re-calibrations suggest questionable reliability of the detector responses. The three units tested were inconsistent in responses to CW agents and produced a wide range of RF values. This re-calibration, re-setting the sensitivity span of the instrument, before use was believed to have caused differences in observed response factors for the CW agents. The calibration process re-established the sensitivity of the detector for isobutylene only. Rechecking the detectors with the calibration gas after the agent challenges repeatedly showed responses lower than the initial calibrated values. This suggested that the detector sensitivity was degraded by exposure to the CW agent vapor. The loss of sensitivity may have had a greater effect on CW agent detection due to differences in physical and chemical characteristics.

It is suspected that these residual effects contaminated the lamps causing unstable readings. The lamps were disassembled and cleaned to restore sensitivity. The lamp surface was found to be cloudy and yellowed. CW agent vapors in combination with the humidity apparently coated the lamp surfaces, which affected the sensitivity of the detectors. These changes in sensitivity were masked by the repeated calibration and sensitivity adjustments. Consequently, responses to the less volatile CW agent vapor were affected. The detectors appeared to function normally with sensitivity restored after a thorough cleaning.

6.2 MINIMUM DETECTABLE LEVELS

The minimum detectable level (MDL) for the ppbRAE instruments (A, B, and C) are presented in Table 1 for each agent at ambient temperatures and low relative humidity (<5% RH). The MDL concentrations are expressed in mg/m³ with the ppm conversion shown in parenthesis. The lowest CW agent concentration exposure to produce three consistent responses in three independent trials is considered the MDL. However, since no alarm threshold was set for these detectors, the MDL values were selected based on detector readings that were somewhat consistent and approximately twice the observed baseline reading.

The current military JSOR requirements for CW agent sensitivity for point detection alarms, the Army's currently established values for Immediate Danger to Life or Health (IDLH), and the Airborne Exposure Limit (AEL) are also listed in Table 1 as references to compare the detector's performance. Army Regulation (AR) 385-61 is the source for the IDLH and AEL values for GA and GB, and the AEL value for HD. Army regulation (AR) 385-61 does not establish an IDLH for HD due to concerns over carcinogenicity.

The ppbRAE units would not detect GA or GB at the JSOR, IDLH, or AEL levels. Two of the units (A and C) detected HD at the JSOR level, but unit B would not respond until exposed to a much higher concentration of HD (10 mg/m³). Units B and C showed very inert responses when challenged with any GB concentration. There were several problems and many "no responses" from the instruments throughout the evaluation. Some of the problems experienced include calibrations not holding, baseline not clearing, power up problems, pump error warnings, batteries not lasting in the cold, and baseline fluctuations.

Table 1. Minimum Detectable Level (MDL) for ppbRAE at Ambient Temperatures and 5% Relative Humidity

Agent and Response Time	Concentration in Milligrams per Cubic Meter, mg/m ³ , With Parts per Million Values in Parenthesis (ppm) And Response Times					
	ppbRAE A MDL	ppbRAE B MDL	ppbRAE C MDL	JSOR*	IDLH**	AEL ***
HD in 90 seconds	0.8 (0.12)	10 (1.51)	1.2 (0.18)	2.0 (0.300) in 120 seconds	N/A	0.003 (0.0005) up to 8 hours
GA in 120 seconds	1.2 (0.18)	4.4 (0.66)	2.2 (0.33)	0.1 (0.015) in 30 seconds	0.2 (0.03) up to 30 minutes	0.0001 (0.000015) up to 8 hours
GB in 120 seconds	3.0 (0.52)	3.4**** (0.58)	No Response up to 17.6 (3.1)	0.1 (0.017) in 30 seconds	0.2 (0.03) up to 30 minutes	0.0001 (0.000017) up to 8 hours

* Joint Service Operational Requirements for point sampling detectors.

** Immediate Danger to Life or Health values from AR 385-61 to determine level of CW protection. Personnel must wear either full ensemble with SCBA for operations or full face piece respirator for escape.

*** Airborne Exposure Limit values from AR 385-61 to determine masking requirements. Personnel can operate for up to 8 hours unmasked.

****Unit B also showed no response at 8.5 mg/m³ (1.5 ppm) GB exposure for 5 minutes.

6.3 RESPONSE FACTORS

No consistent RF for the instruments at any condition could be determined. RF values for a compound should be constant with varying concentrations. Results consolidated in Table 2 reflect the wide ranges of RFs observed by the tested units at different concentrations and conditions, by presenting the highest and the lowest RF calculated from results at each tested condition. The RFs are reported as NR (No Response), instead of zero, when a detector failed to

respond. Essentially, this avoids a value of zero for the denominator in the RF equation which would cause the RF to go to infinity.

The results of an earlier RAE Systems' detector (miniRAE Plus), previously tested in 1998, are also shown for comparison between the two instruments. According to the manufacturer, the ppbRAE is an improved model of the MiniRAE Plus. Test results comparing the two instruments showed mixed conclusions. RF factors, while better for some test conditions, were worse for other test conditions. Overall improvement of the ppbRAE over the MiniRAE Plus was not seen in this evaluation.

Table 2. Range of Response Factors for the ppbRAE against HD, GA, and GB at Various Conditions with Corresponding MiniRAE Plus Results

Agent	Average Temperature , °C	Average Relative Humidity, %	MiniRAE Plus*		ppbRAE	
			Lowest RF**	Highest RF	Lowest RF	Highest RF
HD	24	<5	0.35	0.86	0.43	1.30
		50	0.55	1.21	0.51	0.95
		90	0.48	1.29	1.46	2.47
	0	<5	0.76	0.93	0.87	1.63
	40		0.43	0.48	1.06	1.62
GA	24	<5	0.74	NR***	0.56	4.97
		50	0.83	NR	0.74	2.38
		90	0.76	0.84	1.60	3.21
	-10	<5	0.55	0.70	0.80	4.50
	40		0.84	1.02	0.93	1.62
GB	24	<5	2.23	NR	4.70	NR
		50	3.32	3.32	6.40	NR
		90	NR	NR	6.79	NR
	-10	<5	2.31	5.80	3.01	5.54
	40		9.75	18.71	5.45	13.67

* Results from 1998 Phase 1 Domestic Preparedness testing of the RAE Systems instrument known as the MiniRAE Plus, which yielded results in ppm instead of ppb units.

** RF = Response Factor which should be constant at varying concentrations

*** NR = No Response. This gives a value of zero for the denominator in the RF equation causing the RF to go to infinity.

6.4 TEMPERATURE AND HUMIDITY EFFECTS

Table 3 lists the response factors (RF) of the ppbRAE detectors at the various test conditions for HD, GA, and GB. The results listed represent multiple challenges with test units at agent concentrations between 0.4 and 42 mg/m.³

The baseline readings and detector responses showed reduced sensitivity with increasing use. This required frequent cleaning of the detector lamps, which appeared cloudy and yellowed. The performance of the units was not significantly improved after cleaning. The manufacturer installed new lamps about half way through the testing to enable continued evaluation of the detectors.

Table 3. Range of Response Factors of ppbRAE units at Several Agent Concentrations and Various Temperature and Relative Humidity Conditions

Agent	Temperature, °C	RH, %	Challenge Concentration		Unit A		Unit B		Unit C	
			mg/m ³	ppm	Lowest t RF*	Highest t RF	Lowest RF	Highest RF	Lowest RF	Highest RF
HD	24	5	0.8	0.12	0.63	0.73	NR**	NR	3.14	NR
			1.2	0.18	0.50	0.53	Not tested	Not tested	0.98	1.05
			2.3	0.35	0.61	0.69	Not tested	Not tested	0.69	0.82
	23	5	10.0	1.53	0.55	0.71	0.53	0.70	0.43	0.51
			42.0	6.44	0.72	1.07	1.03	1.30	0.87	0.94
	24	50	1.3	0.20	0.51	0.58	Not tested	Not tested	0.81	0.95
	20	90	1.5	0.23	1.46	1.84	Not tested	Not tested	1.92	2.47
	0	3	0.8	0.11	1.02	1.63	1.08	1.54	0.87	1.16
GA	24	5	1.0	0.16	1.50	1.62	1.29	1.31	1.06	1.08
			0.65	0.10	1.99	2.27	Not tested	Not tested	Not tested	Not tested
			1.2	0.18	0.77	1.00	5.63	36.1	Not tested	Not tested
			2.2	0.33	1.21	1.61	6.12	NR	0.56	0.62
			3.3	0.50	2.09	2.21	10.12	NR	Not tested	Not tested
			4.4	0.66	1.79	2.30	4.47	4.97	0.81	0.90
		50	3.7	0.56	2.32	2.38	NR	NR	0.74	1.13
		90	4.1	0.62	2.89	3.21	NR	NR	1.60	3.18
	-10	0	0.4	0.05	1.72	4.50	2.02	2.09	Not tested	Not tested
			0.8	0.11	0.80	1.97	0.99	1.01	Not tested	Not tested
	40	3	0.42	0.07	1.01	1.55	1.17	1.39	Not tested	Not tested
			0.85	0.14	0.93	1.13	1.04	1.62	Not tested	Not tested
GB	24	5	3.0-3.4	0.52-0.98	4.70	9.62	6.63	NR	Not tested	Not tested
			8.5	1.48	7.63	9.02	NR	NR	Not tested	Not tested
			17.6	3.06	9.31	13.93	Not tested	Not tested	69.63	NR
	20	62	3.7	0.64	NR	NR	9.08	17.65	Not tested	Not tested
			3.7	0.64	8.47***	31.77***	4.18***	9.77***	Not tested	Not tested
	24	50	3.9	0.68	6.40	7.00	NR	NR	NR	NR
		90	3.2	0.56	6.79	8.07	Not tested	Not tested	NR	NR
	-10	0	1.7	0.26	3.01	3.36	3.16	3.40	Not tested	Not tested
			3.2	0.49	4.61	5.54	4.14	5.30	Not tested	Not tested
	40	3	1.9-3.8	0.35-0.70	5.45	10.10	5.81	13.67	Not tested	Not tested

* RF = Response Factor which should be constant at varying concentrations.

** NR = No Response. This gives a value of zero for the denominator in the RF equation causing the RF to go to infinity.

***Response after lamps were cleaned and test repeated

Agent challenge times of approximately 90 seconds for HD and 120 seconds for GA/GB allowed the maximum detector response. After that time, the detector responses fluctuated around that value. In addition, the elapsed time required for the detector reading to return to the baseline value after the agent challenge (clear down time) was noted for each trial. Frequently, the baseline drifted and the units never returned completely to the original baseline values. The baseline responses were unstable with large fluctuations throughout the evaluations and did not appear to be caused by temperature and relative humidity changes.

During agent challenges, no conclusive temperature and RH effects could be determined due to the large range of detector readings and the inconsistencies of the three units. However, at the cold and hot temperature extremes, the detectors responded to lower than MDL agent

concentrations for GA and GB. In general, cold temperatures yielded increasing detector responses after agent exposure was stopped and/or longer recovery times.

All detectors developed symptoms of contamination that seemed to cause erratic detection of the CW agents throughout the evaluation. When any given unit was experiencing problems, the two best working units would be tested on that day. Therefore, the results listed in Table 3 contain many “not tested” situations.

7. CONCLUSIONS

Conclusions are based solely on the results observed during this testing, except for the comparison of the MiniRAE Plus results from prior testing. Aspects of the detectors, other than those described, were not investigated.

Civilian first responders and HAZMAT personnel use Immediate Danger to Life or Health (IDLH) values to determine levels of protection selection during consequence management of an incident. The ppbRAE units could not detect GA or GB to meet JSOR, IDLH or AEL values. Two out of the three units were able to detect HD at the JSOR level but none of the units was able to meet the AEL detection requirements for HD.

These detectors exhibited wide ranges of response factors (RF) values between units as well as within the same unit. They displayed varied and inconsistent ppb values when exposed to similar concentrations of CW agent vapors. Consequently, no meaningful RF versus agent concentration relationship could be determined.

Residual effects from CW agent challenges and/or calibration drift were observed. The UV lamps used by the ppbRAE units to ionize the vapor samples for detection are easily contaminated by dust, dirt, moisture, and other exposure residue. Frequent and thorough cleaning is required to maintain detector performance. However, it may not be practical for first responders to calibrate and replace/clean the lamps after each use.

Testing was discontinued after the agent sensitivity, temperature, and relative humidity tests, based on the poor performance of these detector units. Further testing of the detectors was considered to be of no value. The instrument behaviors were similar to the MiniRAE Plus, an earlier version of this instrument reported in 1998.

The fact that these detectors required frequent cleaning when operated in the clean laboratory environment during this evaluation suggests that the detectors would require many more cleanings when operated in the damp, dusty, and smoky field environments common during emergency response situations. Under these conditions, the detector response to CW agents would be masked.

LITERATURE CITED

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1. Longworth, Terri L. et al, Testing of Commercially Available Detectors Against Chemical Warfare Agents: Summary Report, ECBC-TR-033, U.S. Army Chemical Research, Development and Engineering Center, Aberdeen Proving Ground, MD, May 1999, UNCLASSIFIED Report.
 2. ATCD-N, MEMORANDUM, Subject: Joint Service Operational Requirement (JSOR) for the Automatic Chemical Agent Detector Alarm (ACADA), HQDA United States Army Training and Doctrine Command, Fort Monroe, Virginia, 3 August 1990.
 3. Operational and Maintenance Manual, ppbRAE PPB VOC Monitor PGM-7240, Document No: 025-4001-000, Rev A, RAE Systems Inc., Sunnyvale, CA, August 1999.
 4. Ong, Kwok Y., Multi-Purpose Chemical Agent Vapor Generation System, ERDEC-TR-424, U.S. Army Chemical Research, Development, and Engineering Center, Aberdeen Proving Ground, MD, July 1997, UNCLASSIFIED Report.
 5. Ong, Kwok Y., et al, Analytical Methodology for Quantitative Determination of O-ethyl-S-(2-Diisopropylaminoethyl) Methylphosphonothiolate (VX), ERDEC-TR-476, U.S. Army Chemical Research, Development and Engineering Center, Aberdeen Proving Ground, MD, March 1998, UNCLASSIFIED Report.